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Art. XI.—*A Correlation between Leaf Dimensions and Osmotic Concentrations in Chickweeds.*

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Introduction.

For many years the succulence exhibited by a large number of coastal and salt marsh plants has been recognised as being due either directly or indirectly to the effect of the sodium chloride and other salts present in the soil. While several experiments have been made to show the effect of varying concentrations of NaCl on such succulent halophytes themselves, few attempts have been made to reproduce the same effect in normal mesophytic plants by adding salt to the medium in which they grow. One of the earliest experiments of this nature was carried out by Batalin (1) in 1876. He found that "salt plants" lose their normal characteristics when grown in non-saline soils, and also that the leaves of *Salicornia herbacea* became succulent if watered with NaCl solutions. Lesage (2), working with *Lepidium sativum*, showed that if a solution of salt was added to the soil the leaves became thicker, the palisade tissue was greatly increased, and there was a reduction in the amount of chlorophyll present. Lesage also stated that with increasing concentration of salt the thickness of the leaf was increased, accompanied by a decrease in the height of the plant and a reduction of leaf surface. Conversely, he stated that with a decrease in salt concentration the thickness of the leaf decreased, accompanied by an increase in height and leaf surface. These latter statements of Lesage, however, are found to be at variance, to a certain extent, with the results obtained in the present investigation into the correlation between salt concentration in the soil and the leaf dimensions of *Stellaria media* and *Cerastium vulgatum*. Rudolfs (6), in 1927, also found that the addition of salt to the soil increased the height of asparagus plants, which is contradictory to Lesage's statement. There is, however, in such cases, always a possibility that the addition of salt may have the effect of increasing the absorption of nutrient food materials from the soil which otherwise would be available in less amount. Further work done on the effect of salt on plants has been concerned mainly with the effect on height, growth, and other features, or with the effect on halophytes themselves.

Methods of Experiment.

Healthy young seedlings of *Stellaria media* and *Cerastium vulgatum* were selected, at approximately the same stages of growth. Five pots of garden soil were set out for *Stellaria*, and five for *Cerastium*, and in each were planted four seedlings. These were watered with the following solutions of sodium chloride: 1 gm./2000 ccs., 1 gm./1000 ccs., 1 gm./500 ccs., and 1 gm./100 ccs. Tap water was used as a control in the fifth pot of the series. Watering of the seedlings was carried out by means of sprinkler-topped bottles containing the solutions. In watering care was taken to add the solution of NaCl until it emerged from the bottom of the pots, so that there should not be any cumulative increase in concentration in the pots as the result of evaporation. The seedlings were watered with salt solution every three days, and if necessary with tap water on the intervening days.

After four weeks the effect of the different solutions of salt on the plants was very marked, a gradation being shown from the control pot up to those to which 1/100 salt had been added. The concentration of 1/100 NaCl proved to be too great for tolerance by the *Cerastium* plants, and at the end of three weeks they began to wilt, finally dying at the end of about four weeks.

As the amount of added salt was increased, the leaves of the plants of both *Stellaria* and *Cerastium* became longer, broader, and slightly thicker, and also appeared more succulent. They became lighter green in colour, and had a more translucent appearance.

In observing the *Stellaria* plants, though the leaves of those watered with 1/2000 NaCl were seen to be slightly larger than those of the control, the first marked increase in succulence was shown by the plants watered with 1/1000 NaCl. They were quite healthy and flowering profusely, but were lighter green in colour than the control. The plants watered with 1/500 NaCl were unfortunately at an earlier stage of growth than those in the other pots, and though showing the same marked features produced by the increase in salt concentration, the dimensions of their leaves could not be measured. A most remarkable contrast was shown when the plants watered with 1/100 NaCl were compared with the control plants. They appeared very succulent, the leaves being so pale in colour as to be hardly green, with a waxy bloom on the epidermis. The stems were thick and succulent, and very light green in colour. The leaves were extremely large and thick, with the petioles bent backwards in a peculiar fashion. The single row of hairs on the stems was apparently unaffected. A further marked difference from the control was the shortness of the internodes. At the end of six weeks, though still flowering quite well, the stems began to wilt at the base.

In order to demonstrate numerically a correlation between the dimensions of the leaves and the concentration of the added salt, ten adult leaves were taken from each pot and measured for

FIG. 1.—Stem and leaves of *Stellaria media*.

A. From a plant watered with 1:1000 NaCl.
B. From a control plant.

length, breadth and thickness. Length and breadth were measured with calipers, the greatest width being taken, and thickness was measured with a Leitz micrometer gauge. The mean values of these dimensions, when plotted against the salt concentrations, show a uniformly rising curve from the control to the 1/100 concentration. An analysis of the tap water used for the control showed only 13 parts per million to be present. Owing to the smallness of this amount the values for the leaf dimensions of the control could not be plotted.

TABLE I.—Mean values of length, breadth, and thickness of *Stellaria* leaves in various concentrations of NaCl.

	Control. cms.	1/2000 NaCl. cms.	1/1000 NaCl. cms.	1/100 NaCl. cms.
Length	1·006	1·325	1·352	1·458
Breadth	0·693	0·735	0·875	0·925
Thickness . . .	0·0322	0·0349	0·0391	0·0454

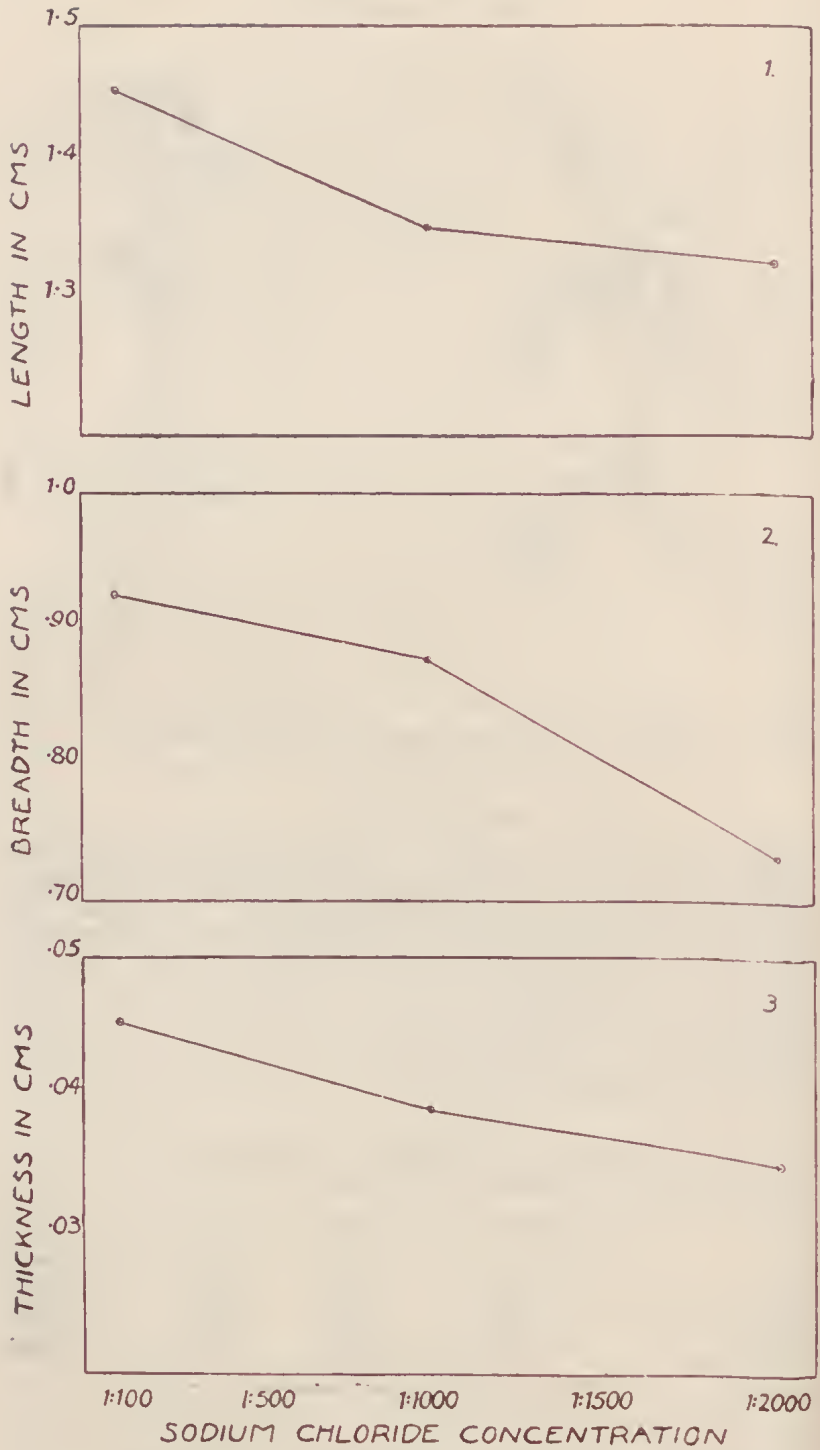

FIG. 2.—*Stellaria media*. Graphs showing increase in (1) length, (2) breadth, and (3) thickness of *Stellaria* leaves with increase in concentration of NaCl.

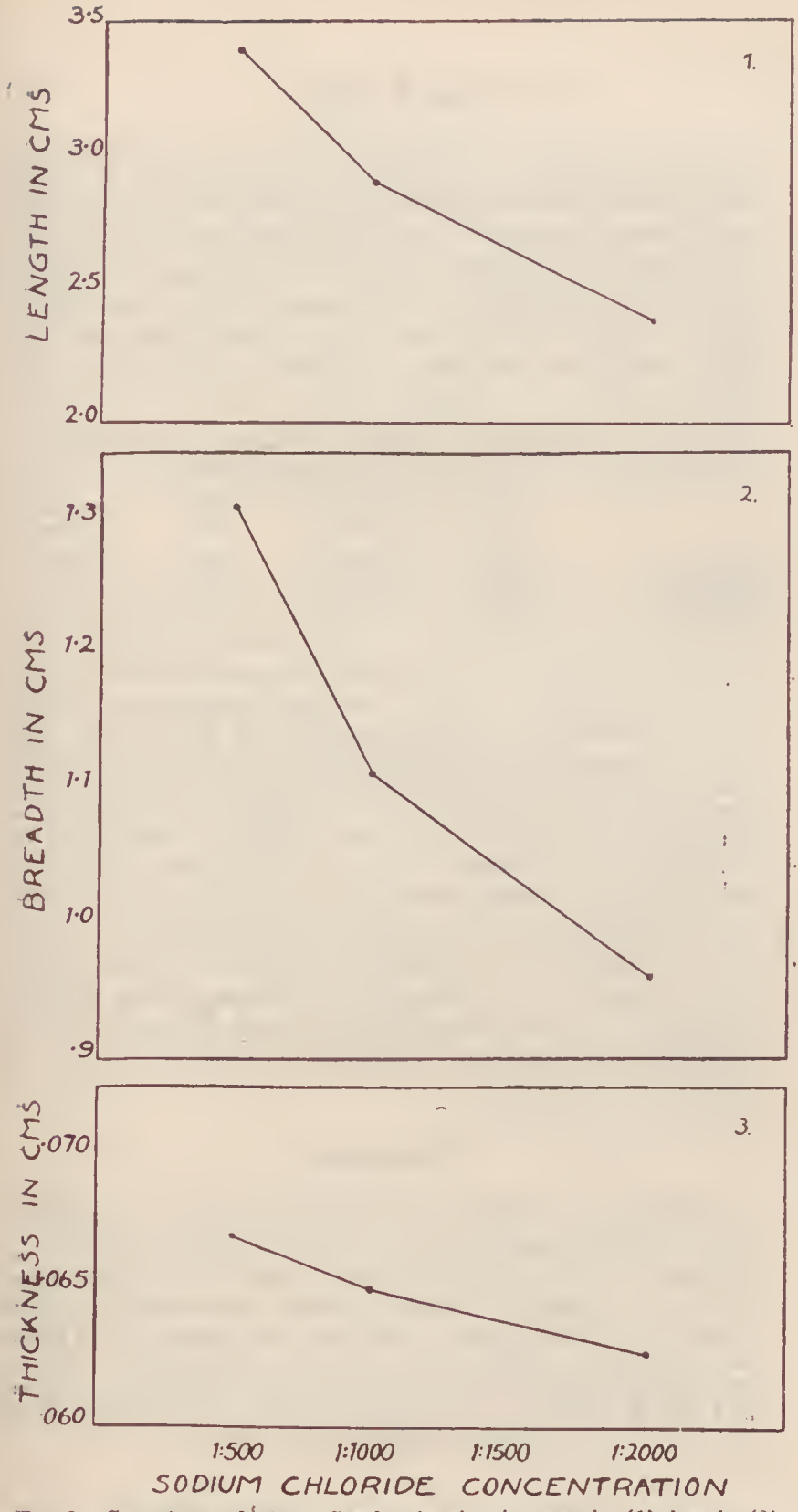

FIG. 3.—*Cerastium vulgatum.* Graphs showing increase in (1) length, (2) breadth, and (3) thickness of *Cerastium* leaves with increase in concentration of NaCl.

The same general features were observed in the experiment with *Cerastium* plants, but in this case a concentration of 1/500 NaCl was the greatest tolerated. The plants watered with 1/500 NaCl, however, showed a very marked increase in leaf dimensions and a similar decrease in the amount of chlorophyll present. No structural differences were shown by the plants, but as the salt increased they showed more vigorous growth, with a great increase in height, and the leaves became much larger and to a certain extent more succulent. No effect on hairiness was observed.

TABLE 2.—Mean values of length, breadth, and thickness of *Cerastium* leaves in various concentrations of NaCl.

	Control. cms.	1/2000 NaCl. cms.	1/1000 NaCl. cms.	1/500 NaCl. cms.
Length	1·85	2·38	2·91	3·41
Breadth	0·805	0·96	1·11	1·31
Thickness . . .	0·0585	0·0627	0·0650	0·0669

The question arises as to whether the increase in leaf surface involves an increase in the total number of stomata, or whether the same number are simply spread over a larger area. The number of stomata on the under epidermis of the leaves from the control *Stellaria* plants, and from the large, fleshy leaves of those watered with 1/100 NaCl have been compared. A number of readings of each have been taken, and it was found that the average number of stomata on the leaves of the control was two and a-half times as great as on the 1/100 NaCl leaves. The area of the 1/100 leaves, however, was approximately only twice as great as that of the control leaves. If the number of stomata were constant on the leaf independently of its size, the ratio of the salt plant to the control plant would have been as 5:2·5 stomata per sq. mm. The actual ratios are 5:2; that is, there is an actual diminution in the total number of stomata. The net result will be a decrease of 60% of the normal value in the average transpiration rate.

Conclusion.

From the above results it is apparent that the direct action of sodium chloride in solution on certain mesophytic plants is to increase not only thickness, but also length and breadth of leaves, and that up to a concentration which is lethal for a specific plant, there is a correlation between osmotic concentration and leaf dimensions. The increase in succulence accompanied by a reduction in the total number of stomata and, consequently, a decrease in transpiration, favours the conservation of water by the plant, and this is necessary as the high osmotic concentration of the salt in the soil retards absorption by the root system.

Summary.

1. Seedlings of *Stellaria media* and *Cerastium vulgatum* were grown in soil watered with solutions of varying concentrations.

2. As the concentration of the salt was increased the leaf dimensions were found to increase. The highest concentration of NaCl which could be added was 1/500 for *Cerastium*, and 1/100 for *Stellaria*.

3. The number of stomata per sq. mm. of leaf surface of *Stellaria* was found to be diminished in high concentrations of NaCl. This was not merely a mechanical effect due to increase in leaf surface, because the total number of stomata was also reduced, thus reducing transpiration.

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